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Any queries on this receipt should be addressed to Janine Geran, tel. 01633 814570. All other enquiries should be directed to Central Enquiry Unit, tel. 0845 9 500 505.

Note : The above filing date is provisional and may need to be amended if the provisions of section 15(1) of the Patents Act 1977 are not met.

P092

PATENT SPECIFICATION

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P092

OPTICAL DEMULTIPLEXER

The invention relates to optical signal demultiplexers and particularly to such devices including a dispersive array integrated on a planar substrate.

Integrated chip optical demultiplexers are known including devices which may have a plurality of opto/electric transducers such as photodiodes added to provide output signals corresponding to the demultiplexed optical signals. When using a row of photo diodes to sense the output from a plurality of output channels, the optical signals of the output channels need to be separated to a spatial extend corresponding to the spacing of the photo diodes. Due to the limitation of small size of photo diode, the optical signals in the output channels need to be separated accordingly. If the optical demultiplexer is formed by an arrayed grating of semiconductor waveguides the spatial separation of the optical output channels can be much closer than can be achieved for an array of photo diodes. Known proposals for such devices include detecting the output channels from the array in a plurality of output waveguides which collect the demultiplexed channels and deliver the light to output locations which are sufficiently spaced to match the array of photo diodes.

It is an object of the present invention to provide an improved optical signal demultiplexer in which the spatial separation of the output channels may be controlled by means other than diverging output waveguides.

The invention provides an optical signal demultiplexer integrated on a planar substrate comprising a dispersive array of optical paths of different optical pathlength on the substrate, said dispersive array having a respective focal line at each end of the array and being asymmetrical at opposite ends such that the output focal line is spaced further from the output end of the array than the input focal line is spaced

from the input end of the array, the spacing of the output focal line being arranged to provide a desired spatial spread of demultiplexed signals.

Preferably a plurality of light detectors are located at the output focal line so as to provide a plurality of output signals representing respectively the demultiplexed signals.

Preferably the light detectors are located on the integrated planar substrate.

The light detectors may comprise an array of photo diodes.

The photo diodes may form a line along or adjacent to an edge of the planar substrate.

Preferably the dispersive array comprises a plurality of optical waveguides.

Preferably the direction of the waveguides are inclined inwardly towards each other at the input end of the array so that the directional axes of the waveguides at the input end intersect at said input focal line.

Preferably a free light propagating region is provided in the substrate between the input end of the dispersive array and said input focal line.

Preferably the direction of the arranyed waveguides are inclined inwardly towards each other at the output end of the array so that the directional axes of the waveguides at the output end intersect at the said output focal line.

Preferably a free light propagating region is provided in the substrate between the output end of the dispersive array and said output focal line.

Preferably the ends of the waveguides of the array terminate in part circular arcs at each end of the array, the arc at the output end of the array being of larger radius than the arc at the input end of the array.

The demultiplexer may be formed as an integrated semiconductor chip.

The dispersive array may comprise a plurality of silicon on insulator waveguides.

Said waveguides may comprise ridge or rib waveguides.

A reflecting mirror may be provided to redirect demultiplexed signals from the output of the dispersive array between the output end of the dispersive array and said output focal line.

Said mirror may be positioned to direct demultiplexed signals through a free propagation region adjacent the input end of the dispersive array prior to reaching the output focal line.

Some embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 is a diagram of a prior art optical signal demultiplexer using output waveguides,

Figure 2 is a view corresponding to that of Figure 1 but showing an embodiment of the present invention,

Figure 3 shows more detail of the position of the output detectors in the device of Figure 2,

Figure 4 is a schematic diagram of a variation of the embodiment of Figure 2, and

Figure 5 shows a similar view of a further embodiment of the invention.

In the schematic prior art arrangement shown in Figure 1, a dispersive waveguide array 11 consists of a plurality of curved waveguides 12. Each of the waveguides has a straight input section 15 and a straight output section 19. Line 13 indicates the junction between the straight input sections 15 and the curved sections 12. Similarly the line 14 indicates the junction between the curved sections and the straight output sections 19. In this case the input and output ends of the array 11 are symmetrical. The straight input sections 15 taper inwards towards each other so as to point to the focus position 17 at the end of the input waveguide 16. Similarly the straight output sections 19 are inclined towards each other so as to form a focus in region 20 adjacent the entrance to an array of output waveguides 21. The geometry of the input and output ends of the array each form part of a similar Rowland circle arrangement. The input ends of the straight waveguide sections 15 lie on an arc forming part of a larger circle 22 having its centre coincident with the end 17 of the input waveguide 16. Point 17 lies on the circumference of an inner circle 23 having half the radius of the larger circle 22. Similarly at the output end of the array 11, the ends of the straight waveguide sections 19 terminate on an arc forming part of a larger circle 24 having its centre coincident with region 20 forming a focus for the output of the dispersive array. The output waveguides 21 are also arranged to terminate in an arc lying on the smaller inner circle 25 which has half the radius of the outer circle 24. Due to the dispersion within the array 11 being dependent on wavelength, the demuliplexed output channels are focussed on an arc of the circle 25 adjacent the output waveguides 21. The channels are closely spaced at the focal

line and are too closely positioned for effective detection by respective photo diodes in the output detectors 26. For this reason the array of output waveguides 21 detect the output channel images formed on circle 25 and transmit the optical signals to more spaced locations at the edge 27 of the chip where the spacing is sufficient to match the separate diode locations in the array of diodes 26.

In the first embodiment of the invention shown in Figure 2, similar reference numerals have been used for similar parts. The demultiplexer is formed as an integrated chip on a planar substrate. The substrate may be formed with silicon on insulator and the waveguides may be ridge waveguides of the type shown in US Patent 5757986. The array 11 is a dispersive array of ridge waveguides formed on the chip 30 with an input arrangement generally similar to that already described for Figure 1 except that a plurality of input waveguides 16 are provided. Any one of the input waveguides may be selected either by selective operation of light sources off chip or by including selectively operable attenuator switches on chip in the input waveguides 16. However the waveguide array 11 is asymmetric in that the output end is arranged to have a focal line much further remote from the ends of the array 11. The ends of the output sections 19 lie on the arc of the large circle 24 which forms a Rowland circle arrangement with the smaller circle 25. However in this case the smaller circle 25 has its circumference lying on the line of output photo diodes 26 at the edge 31 of the chip. The circle 24 has a diameter much larger than the input Rowland circle 22. In this way, the output focal line which now lies on the line of photo diodes 26 is spaced from the output end of the array 11 by a distance much greater than the distance between the input focal plane 17 and the input end of the array 11. The spacing of the optical signals in the output channels formed on the detectors 26 is dependent on the spacing between the output focal line and the end of the array 19. This increased distance is achieved by arranging that the straight output sections 19 of the array 11 have much less angle of inclination towards each other than is the case for the straight input sections 15 for the array 11. By arranging the inward inclination of the

output ends 19 of the array 11 it is possible to arrange the spacing of the output focal line to achieve the desired spacing of the optical signals in the output channel where the output signals are brought to a focus. By suitable location on the chip 11 the output channels can be focussed directly onto the output photo diodes without the use of further output waveguides such as those marked 21 in Figure 1. Figure 3 shows more detail of the output image formation. The demultiplexed signals form a plurality of channels extending between a "first" channel and a "last" channel shown in Figure 3. The channel outputs are focussed on the arc of the Rowland circle 25 with the first and last channels being focussed at the opposite edges of the array where line C crosses the Rowland circle 25. The centre channel is focussed at the point where line A forms a tangent to the Rowland circle 25. The photo diodes 26 are positioned on line B substantially mid way between lines A and C.

It will be appreciated that in the construction of the semiconductor chip described with reference to Figure 2, the chip regions adjacent to each end of the array 11 form free propagation regions through which light can be transmitted in the slab of semiconductor material.

Figure 4 shows a variant on that of Figure 2, in this case similar reference numerals have been used for similar parts. In this case the array 11 is located at one end of an elongated chip 35. This allows a longer pathlength between the output of the array 11 and the output focal line. In this case the array of photo diodes are located at position 26 on an edge 36 of the chip at its furthest end remote from the array 11. In this case the radius of the larger Rowland circle 24 is such that the centre of the circle lies on the array of photo diodes 26. In this example the input waveguide 16 is shown connected to an external optical fibre 37 providing a multiplexed optical input signal. Although the input shows a single waveguide 16, a plurality of input waveguides 16 may be used as shown in Figure 2.

A further variant is shown in Figure 5. In this case the chip 38 has an asymmetric 11 similar to that previously described. The input to the array 11 is generally similar to that already described and the region 41 lying between the input waveguide, or waveguides, 16 and the array 11 forms a free propagation region for the light signals lying within the larger Rowland circle 22. The output of the array 11 has the output waveguides directed inwardly only slightly so as to provide a long pathlength to the focal line for the output signals. In this case the output is initially directed towards end 42 of the chip but is reflected by a plain mirror 40 located in the optical output path prior to reaching the output focal line. Light is reflected by the plain mirror 40 through the free propagation region 41 to a position where the focal line is formed at edge 43 of the chip. The focal line is close to the sensitive surface of the array of photo diodes as previously described. It will be appreciated that the distance to the focal line is determined by the radius of the large Rowland circle 24 determined by the directions of convergence of the output waveguides of the dispersive array 11.

It will be appreciated that in each of the above embodiments, the increased distance between the dispersive array and the output focal line enables sufficient spacing of the output channel images to enable the light to be incident directly on the photo diode array even allowing for the physical size necessary for the discrete photo diodes in the array. Furthermore, all light from the dispersive arrays is directed onto the line of photodetectors. In the case of using output waveguides such as those marked 21 in Figure 1, some losses inevitably occur due to light which forms part of the output image but which is not conveyed through the waveguides due to the physical size, mode field shape and physical separation between adjacent waveguides in the output array. It is not possible for an array of waveguides side by side to detect the entire light forming the image of the output channels at position 20 in Figure 1. However in the embodiment described above the entire light output from the array is directed onto the photo diodes thereby resulting in a much reduced loss of light intensity and light signal data which can be detected and used by the

photodiodes in generating electrical signals indicating the result of the signal demultiplexing.

The invention is not limited to the details of the foregoing examples. The photodiodes 26 may comprise an array of photodiodes or a set of photodiodes on individual chips at the edge of the demultiplexer chip 30.

CLAIMS:

1. An optical signal demultiplexer integrated on a planar substrate comprising a dispersive array of optical paths of different optical pathlength on the substrate, said dispersive array having a respective focal line at each end of the array and being asymmetrical at opposite ends such that the output focal line is spaced further from the output end of the array than the input focal line is spaced from the input end of the array, the spacing of the output focal line being arranged to provide a desired spatial spread of demultiplexed signals.

2. A demultiplexer according to claim 1 in which a plurality of light detectors are located at the output focal line so as to provide a plurality of output signals representing respectively the demultiplexed signals.

3. A demultiplexer according to claim 2 in which the light detectors are located on the integrated planar substrate.

4. A demultiplexer according to claim 2 or claim 3 in which the light detectors comprise an array of photo diodes.

5. A demultiplexer according to claim 4 in which the photo diodes form a line along or adjacent to an edge of the planar substrate.

6. A demultiplexer according to any one of the preceding claims in which the dispersive array comprises a plurality of optical waveguides.

7. A demultiplexer according to claim 6 in which the direction of the waveguides are inclined inwardly towards each other at the input end of the array so that the directional axes of the waveguides at the input end intersect at said input focal line.

8. A demultiplexer according to claim 7 in which a free light propagating region is provided in the substrate between the input end of the dispersive array and said input focal line.

9. A demultiplexer according to any one of claims 6 to 8 in which the direction of the waveguides are inclined inwardly towards each other at the output end of the array so that the directional axes of the waveguides at the output end intersect at the said output focal line.

10. A demultiplexer according to claim 9 in which a free light propagating region is provided in the substrate between the output end of the dispersive array and said output focal line.

11. A demultiplexer according to any one of claims 6 to 10 in which the ends of the waveguides of the array terminate in part circular arcs at each end of the array, the arc at the output end of the array being of larger radius than the arc at the input end of the array.

12. A demultiplexer according to any one of the preceding claims formed as an integrated chip.

13. A demultiplexer according to claim 12 in which the dispersive array comprises a plurality of silicon on insulator waveguides.

14. A demultiplexer according to claim 13 in which said waveguides comprise ridge or rib waveguides.

15. A demultiplexer according to any one of the preceding claims in which a reflecting mirror is provided to redirect demultiplexed signals from the output of the dispersive array between the output end of the dispersive array and said output focal line.

16. A demultiplexer according to claim 15 in which said mirror is positioned to direct demultiplexed signals through a free propagation region adjacent the input end of the dispersive array prior to reaching the output focal line.

17. A demultiplexer substantially as hereinbefore described with reference to and as shown in Figure 2 or 3 or 4 of the accompanying drawings.

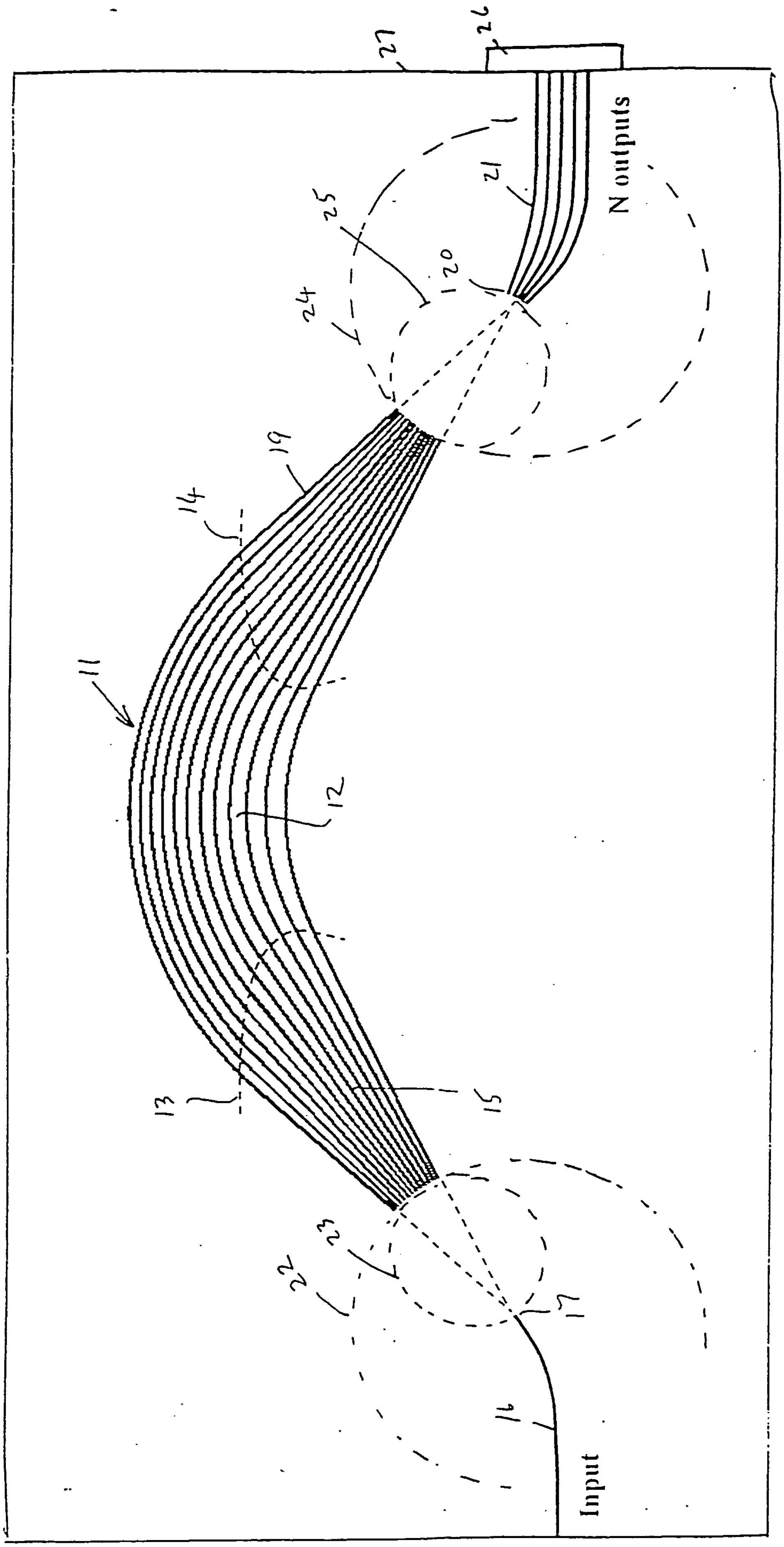


FIG 1

PRIOR ART

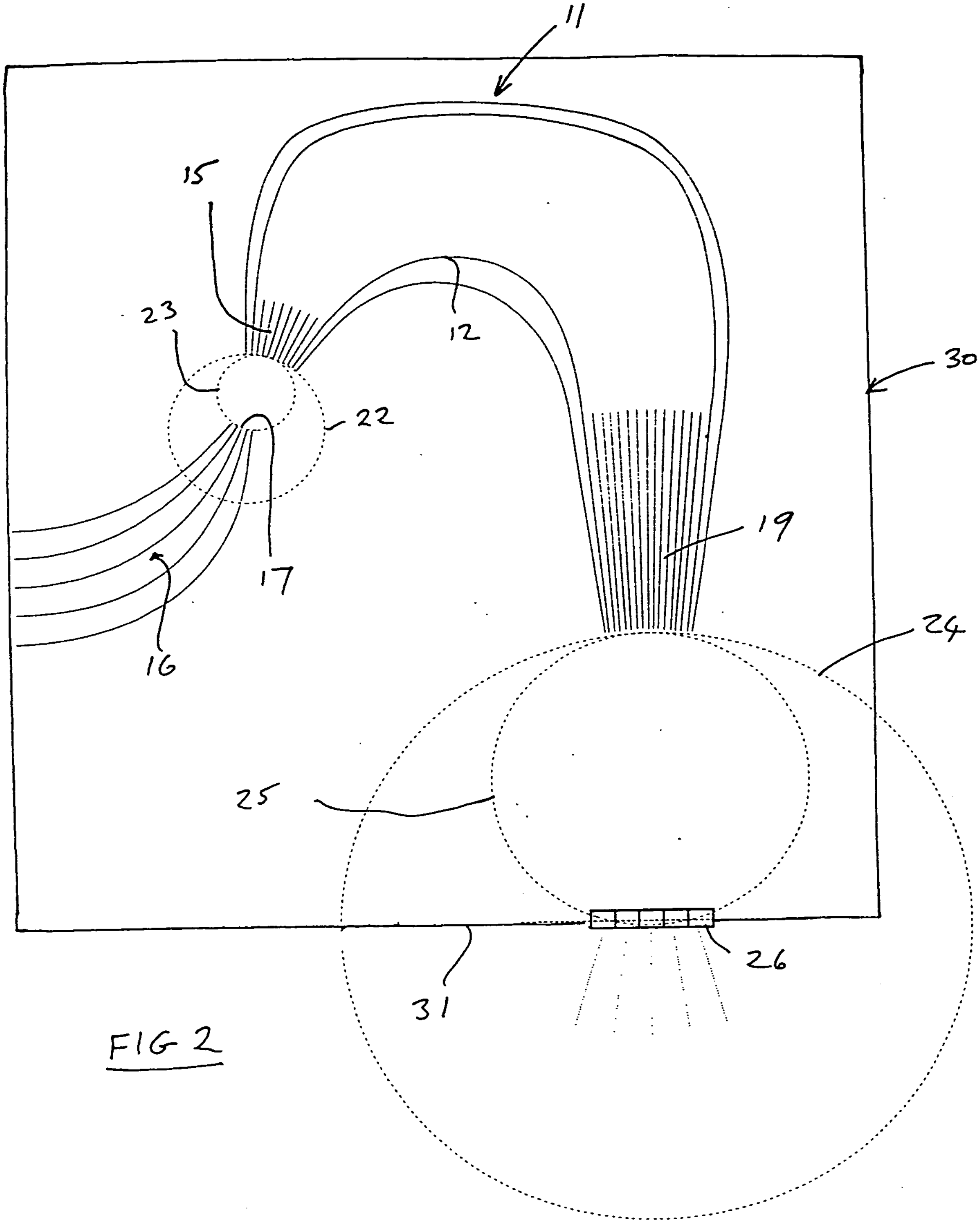
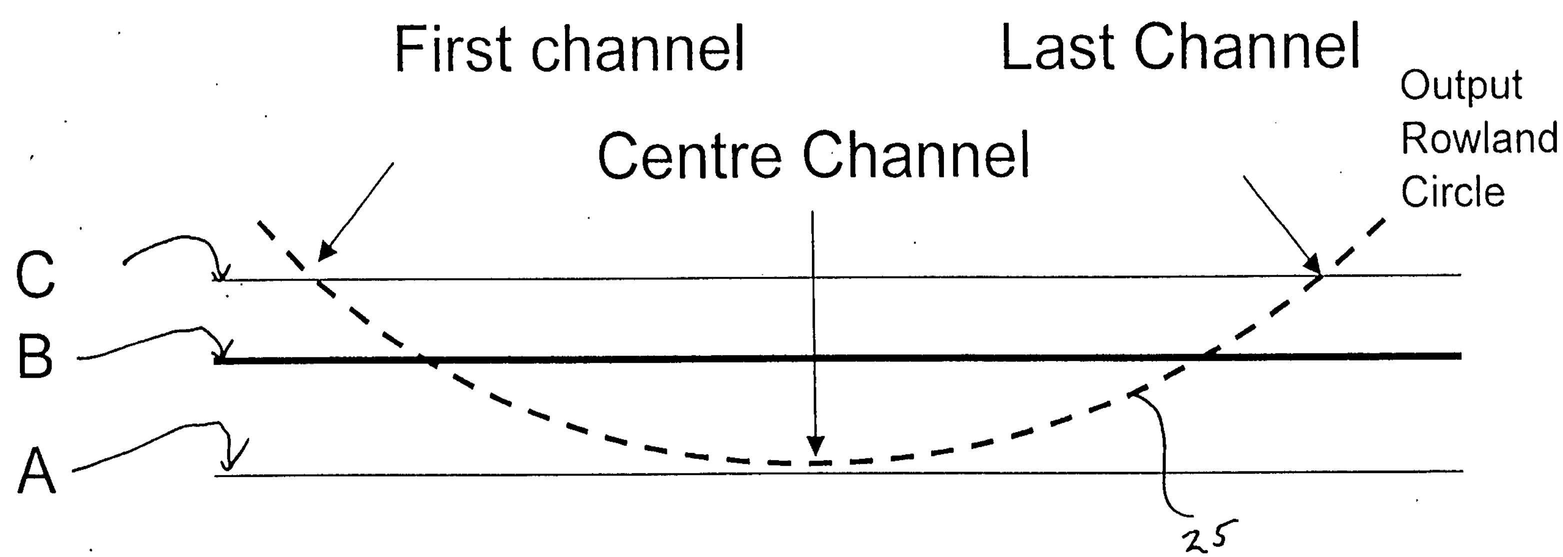


FIG 2

FIG 3



A is a tangent to the Rowland circle at the centre channel
B is the line for position of optical detectors, anywhere between A and C
C is a line from the first channel focus to the last channel focus

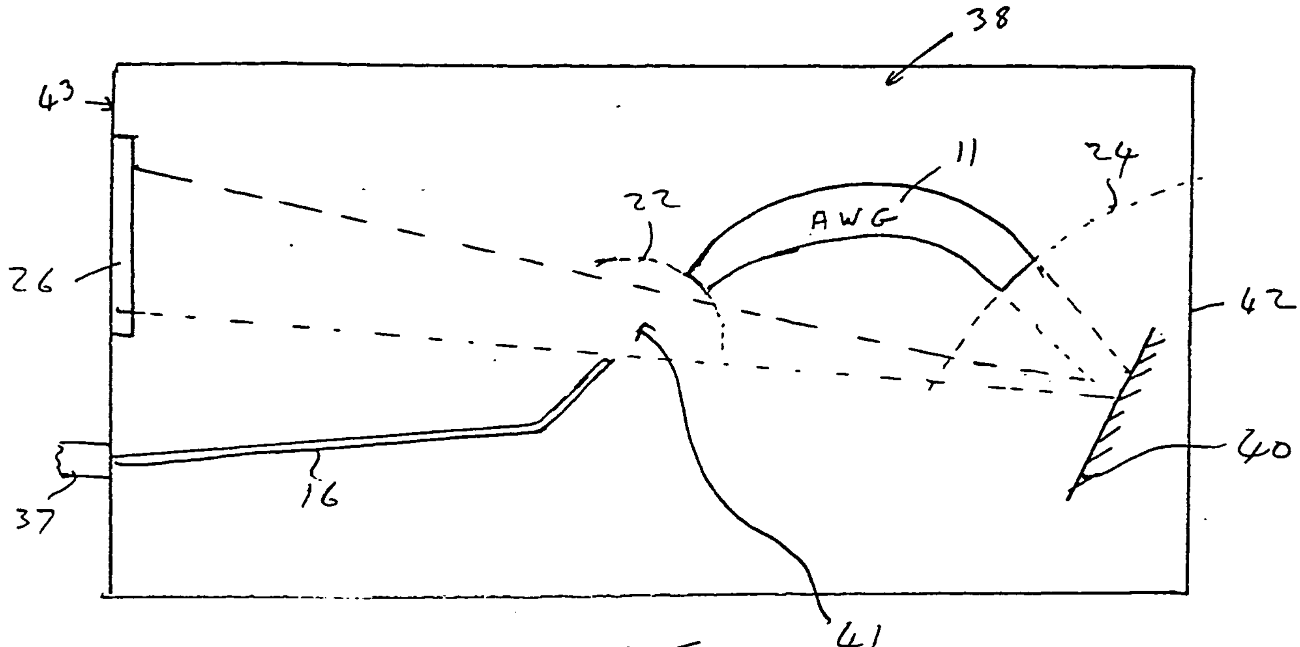


FIG ~~4~~ 5

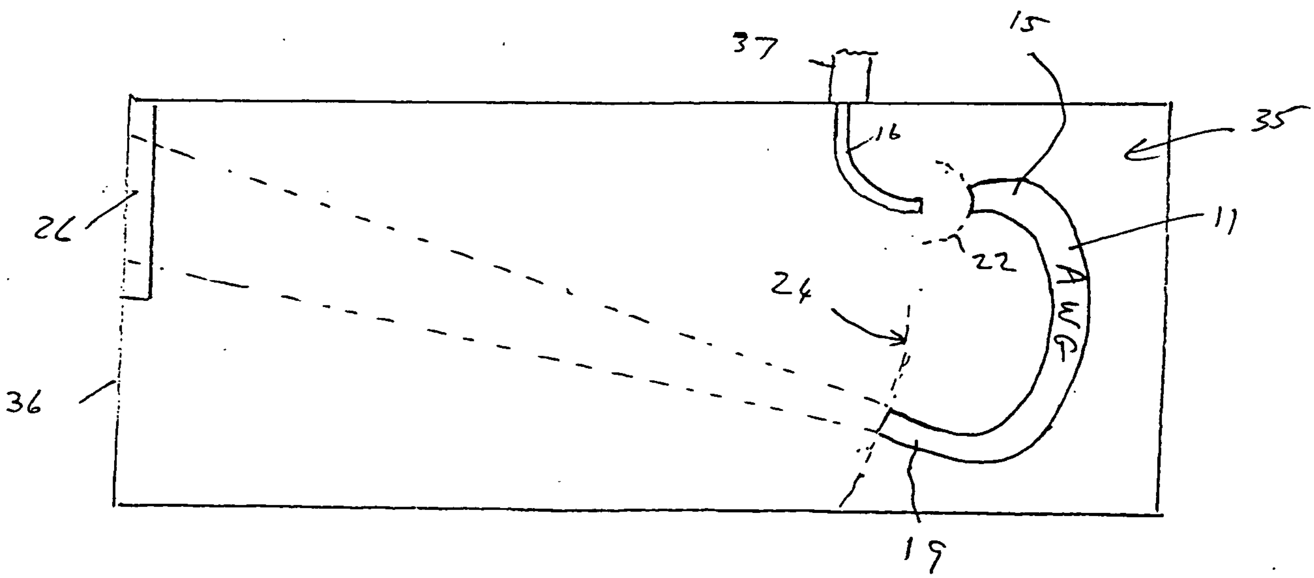


FIG ~~3~~ 4